1. PREFACE

With the convergence of data and telephony services, with the technical advancements in the area of voice over packet technology (DSP and ATM switch fabric devices), and with good progress in the ATM Forum for standardizing voice over ATM (LES specifications), many of the leading network providers (ILECs and CLECs) are gearing up to provide derived line services over xDSL in a major way.

Consequently, the telecommunication industry is debating the best network architecture for delivering VoDSL, which begs the question: Should the network providers invest in DLCs, or in DSLAMs, or in both? The intent of this paper is to answer this question from a network architecture perspective.

2. VoDSL AS A SERVICE

Voice over digital subscriber line (VoDSL) is a common term used to describe a system that carries additional (or derived) "plain old telephone service" (POTS) on a digital loop (twisted pair to the home) using one of the xDSL physical interfaces for layer 1, using ATM for layer 2, or using IP for layer 3. For the ATM case, voice is converted from analog to PCM, to ATM and then back to PCM. The correct term for this service is actually Voice over ATM (VoATM) since voice samples are packed in ATM cells rather then being embedded in the physical ADSL frame. However, the term VoDSL is being used in industry and we will use it interchangeably with VoATM throughout this paper.

The purpose of VoDSL/VoATM is to provide additional voice service over a single copper pair that carries the baseband analog (lifeline) voice circuit and ATM/ADSL data service. The ATM Forum has standardized this service and it is known as Loop Emulation Service (LES). The voice cells from the CPE are terminated at an ATM/TDM gateway, named Voice over ATM (VoATM) Gateway in the remainder of this paper, which translates ATM cells back to TDM traffic.

VoDSL can support up to 16 derived POTS per DSL line (plus the baseband POTS itself) and may be expanded in the future to include other services. VoDSL provides the operator with copper relief. That is, only one twisted pair of copper wires is required per home. It also saves money on sending a craftsperson out each time a new phone line is ordered. And finally, voice and data services are integrated into a single managed system.

EXHIBIT

3. THE VoDSL/VOATM GATEWAY

The VoATM gateway's main functions are to provide PCM/ADPCM conversion, TDM/ATM conversion, silence detection and removal and echo cancellation. Echo cancellation is required because of the large delay from packetization. The VoATM gateway may be located at any one of several points in the network. Some of the possible network architectures will be described.

4. END-TO-END NETWORK ARCHITECTURE FOR VoDSL/VoATM

VoDSL, as a service where voice is transported over ATM/ADSL to a VoATM gateway that interfaces with a Class-5 switch, could be provided through the following two network architectures:

- Centralized VoATM Gateway network architecture
- Distributed VoATM Gateway network architecture

The two network architectures will be described next.

4.1. Centralized VoATM Network Architecture for Derived POTS

In this network architecture voice over ATM traffic is passed through the DSLAMs to where the voice VCs are terminated on a standalone VoATM gateway "behind" the ATM network. The VoATM gateway extracts the voice samples and telephony signaling from the ATM stream, and interfaces with a Class-5 switch over standard TR-008/GR-303 interfaces.

Since the VoATM Gateway may be supporting many DSLAMs (possibly supporting hundreds of thousands of subscribers), it is most likely a large standalone network element with its own ATM switching, protection switching, and network management capabilities.

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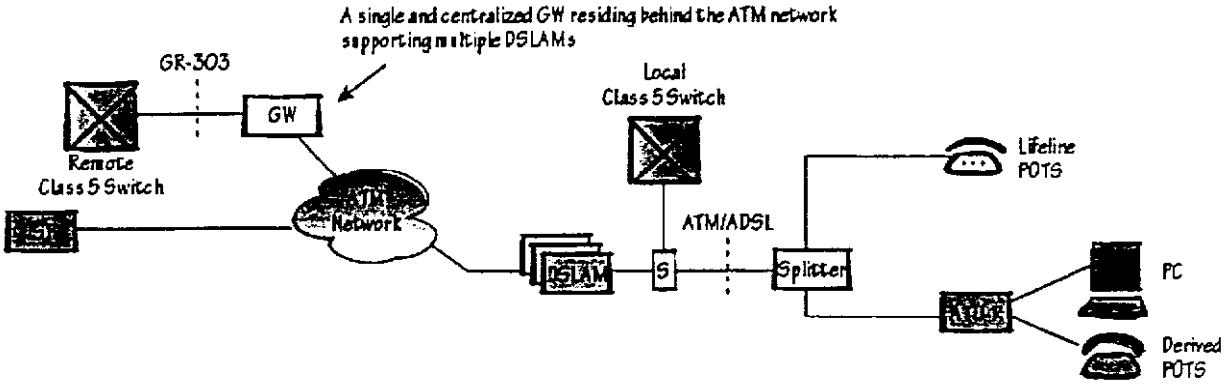

Figure 1. Centralized VoATM Network Architecture

It should be noted that since voice traffic is transported across the ATM network, the Class-5 switch terminating the VoATM traffic is most likely located in a different (remote) serving area than the subscriber. Therefore, unless some telephone number mapping is performed by the network provider, the derived lines could have a different area code than the main lifeline POTS.

4.2. Distributed VoATM Network Architecture for Derived POTS

In this network architecture voice over ATM traffic, in a specific loop area, can be terminated on an integrated and multi-service DLC/DSLAM/Gateway network element, like Alcatel's Litespan system. The voice VCs are terminated on the DSLAM part of the integrated DLC/DSLAM. Voice samples and telephony signaling are extracted from the ATM stream and sent to the DLC part of the integrated DLC/DSLAM, which interfaces with a Class-5 switch over standard TR-008/GR-303 interfaces.

Since the VoATM Gateway is basically supporting a small serving area (in comparison to the centralized VoATM Gateway), it could be designed to fit within the DLC/DSLAM thus utilizing the same platform providing protection switching, ATM switching, and network management capabilities.

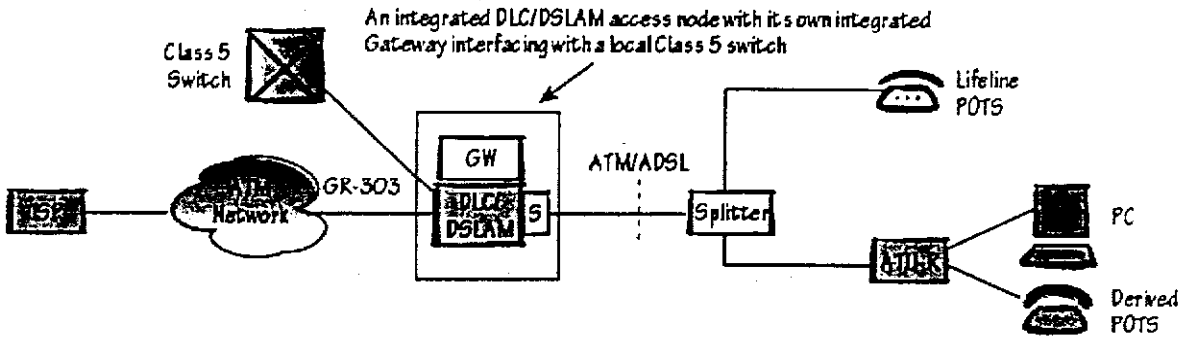

Figure 2. Distributed VoATM Network Architecture

Since the same Class 5 switch is used to terminate regular POTS and derived POTS lines, a subscriber can get local telephone numbers with the same area code, and with similar features.

This architecture is very attractive for both the ILEC and CLEC markets, as will be described later. It allows next generation digital loop carriers (NGDLC) like Litespan to be positioned as the access gateway [1], serving as an integrated multi-service DLC/DSLAM/Gateway network element.

5. END-TO-END FLOWS FOR AN INTEGRATED DLC/DSLAM/GATEWAY

Derived user (voice) traffic flows between the subscriber regular phone and the PSTN network as shown below. There is only one packetized and local voice segment between the ATU-R and the integrated DLC/DSLAM/Gateway, which is defined by the ATM Forum LES specification. The voice samples are extracted from the ATM payload by the VoATM Gateway in the DLC/DSLAM and passed to the Class-5 switch over standard TR-57/TR-008/GR-303 interfaces.

If the DLC already has an integrated DSLAM, then the VoATM Gateway is a modest addition to the overall access node, but with major strategic importance.

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[1] The term access gateway is generally used here to include voice over ATM, voice over IP, or a protocol conversion from one transport technology to another.

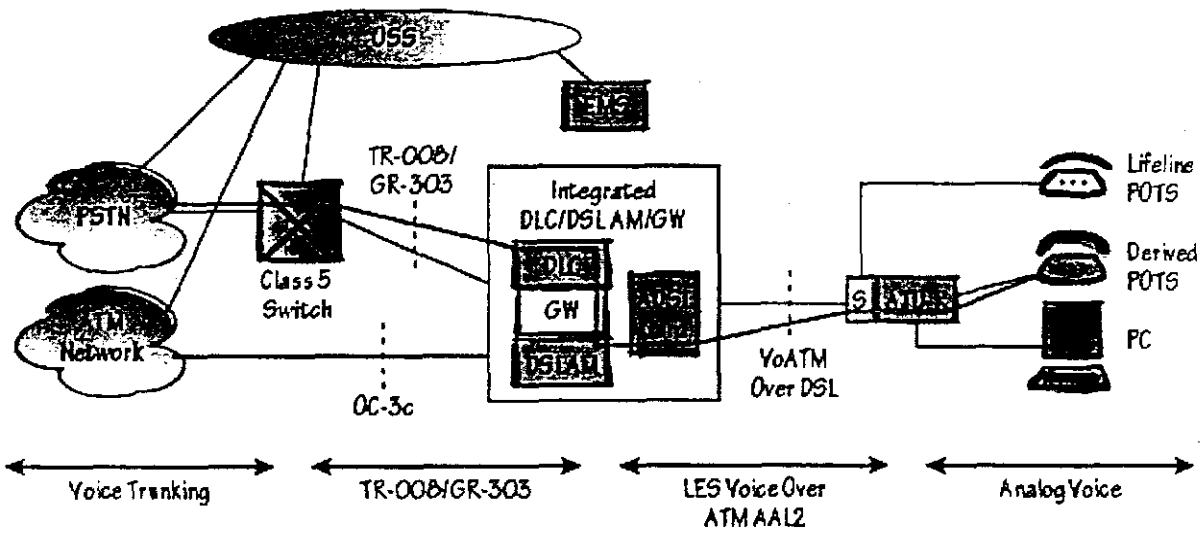

Figure 3. End-to-end U-Plane Flow

It should be noted that at the other side of the PSTN a subscriber with a derived POTS line or regular POTS line could exist. The derived line service should compare in quality and clarity to the telephony service already available.

6. THE CASE FOR AN INTEGRATED DLC/DSLAM/GATEWAY

An integrated DLC, DSLAM, and VoATM Gateway may offer the best network architecture for the network/service providers for the following reasons:

- **Ability to offer telephony and data services from the same access platform**

  A network/service provider needs not buy and maintain multiple types of access network elements (DLCs, DSLAMs, and VoATM Gateways) to offer telephony services (POTS or derived POTS) in addition to data services. A single integrated network element should suffice for data and telephony services.

- **Ability to offer a scalable VoATM Gateway in the access node**

  When the DSLAM and the VoATM are integrated in a DLC, the VoATM Gateway could be engineered to scale up or down with the DLC/DSLAM size. This allows the network provider to invest gradually and deploy derived line services based on market demand.

- **Ability to serve subscribers outside the reach of the central office**

  Network providers have deployed DLCs in the network in order to reach subscribers who are more then 18 Kft

away from the central office to provide basic telephony services. With an integrated DLC/DSLAM, data services can also be provided from the NGDLCs. Moreover, with NGDLC's ability to chain multiple remote terminals (RTs), telephony and data services can be provided to customer deep into rural areas.

- **Ability to capitalize on a huge embedded base of DLCs**

  Network providers have already invested heavily in the DLC market in order to conserve on the Class-5 switch interface, and to serve customers who are far from the immediate reach of the central office. While some DLCs cannot be upgraded to support ATM switching and general gateway functions, other NGDLC systems such as Alcatel's Litespan are upgradeable from a traditional DLC supporting TDM-only functions to an integrated DLC/DSLAM/Gateway access system without effecting the existing POTS service. Moreover, the network provider can rely on an already developed and tested Class-5 interfaces, like TR-057, TR-008, and GR-303.

- **Ability to serve POTS lines and derived POTS lines from the same Class-5 switch**

  Since the VoATM Gateway is co-located within the same CO, the same Class-5 switch is used to terminate regular POTS lines and derived POTS lines. Consequently, derived lines could have the same area code and exchange number as regular lines and the customer will not see any phone numbering difference.

- **Ability to tap on existing carrier-class and fully redundant DLC platform**

  The NGDLC technology is a mature technology that has served TDM/telephony services with carrier-class capability for over ten years. Most NGDLCs are deployed with redundant common circuit configuration with more than 99.99% availability. Integrating ATM capability (DSLAM) and TDM-to-ATM capability allows the new services to use the existing stable, mature and reliable infrastructure.

- **Ability to capitalize on the a huge embedded base of DLC**

  There are tens of thousands of DLC nodes serving millions of users throughout the United States. Each drop (line) in each DLC node is a candidate for a derived POTS line with a mere card upgrade and software download.

- **Simple VC management**

  Since the voice over ATM traffic does not traverse the backbone ATM network but is terminated in the local loop, only one VC segment is needed between the AID/ATU-R and the DLC/DSLAM/Gateway. A single PVC between the AID/ATU-R and the DLC/DSLAM/Gateway with default VPI/VCI values is sufficient to carry all the derived line traffic. This model could migrate easily to the SVC model when so desired by the network provider.

- **Less delay and less echo problems**

  Since the voice over ATM traffic does not traverse the backbone ATM network but is terminated in the local

loop, minimum delay and delay variation is incurred in the ATM domain, thus allowing for a derived line service that is comparable to regular POTS service.

- **Ability to use a unified element management for POTS, data, and derived POTS services**

  With a single access element supporting telephony and data services, a single and unified element management system (EMS) is needed to manage the plurality of services offered by the network provider. This is a major cost saving for the network provider from equipment cost and from human support and administration point of views.

- **Ability to offer ATMized voice service for regular POTS lines**

  The one area where an integrated multi-service DLC/DSLAM/Gateway shines the most is in its ability to support a reverse derived line service, or regular POTS to ATMized voice from existing DLCs. This architecture is shown in Figure 4.

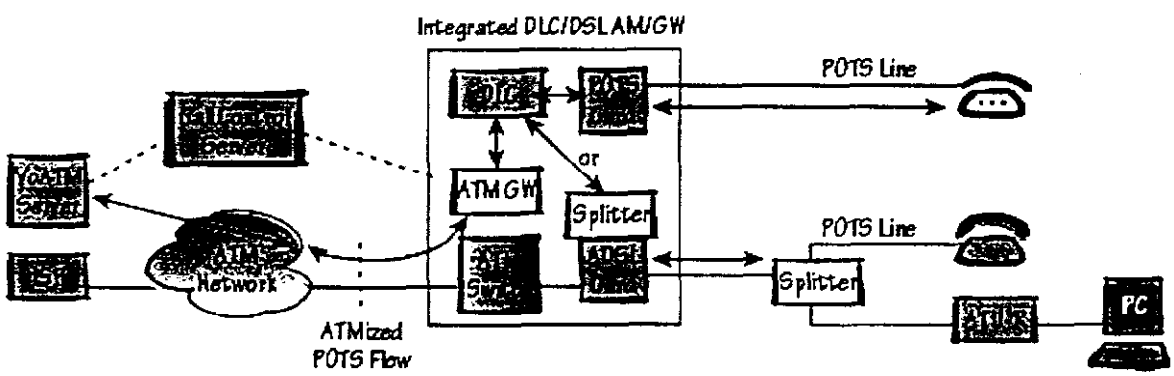

Figure 4. ATMized POTS Service

With the right DLC, regular POTS traffic, whether passing through regular POTS linecards or through a splitter off an ADSL linecard, is passed to the VoATM Gateway for AAL2 encapsulation. The ATMized voice traffic flows through the backbone ATM network to a VoATM server. This architecture is tied to the SoftSwitch architecture and it is our expectation that a protocol such as MGCP or MEGACO[2] will be used for call and connection control between the integrated DLC/DSLAM/Gateway and a Call Control server.

[2] Both protocols are good candidates.

7. CONCLUSION

A clean, elegant, and powerful network architecture is achieved when an integrated multi-service DLC/DSLAM/Gateway is deployed to support telephony and data services. In advanced DLCs which integrate DSLAM and gateway functions in one network element, i.e. VoATM Gateway, a network provider can continue to capitalize on its existing and planned investment in DLCs and migrate to support data and packetized voice services. In essence, the next generation of DLCs, such as the Litespan-2000/Litespan-2012 systems, become the Access Gateway for a distributed network architecture that offer enhanced telephony and data services.

8. REFERENCES

1. I.363.2, ITU-T Recommendation I.363.2, *B-ISDN ATM Adaptation Layer—Type 2 AAL*, 09/97.
2. I.366.1, ITU-T Recommendation I.366.1, *Segmentation and Reassembly Service Specific Convergence Sublayer for the AAL Type 2*, 06/98.
3. I.366.2, ITU-T Recommendation I.366.2, *AAL Type 2 Service Specific Convergence Sublayer for Trunking*, 02/99.
4. ATM Forum AF-VTOA-0113.000, *ATM Trunking Using AAL2 for Narrowband Services*
5. ATM Forum STR-VTOA-LES-01.00, *Loop Emulation Service Using AAL2*, December, 1999.
6. ADSL Forum 99-204, *Recommended Interoperability Implementation Agreement for BLES*, CopperCom and Alcatel, August, 1999.
7. ATM Forum 99-0392, *Loop emulation service and new profile definition for voice over AAL2*, Alcatel USA, July, 1999.
8. ATM Forum 99, *Proposed default NA parameters for Table B-1 of the baseline text of Loop Emulation Service using AAL2*, Joerger and Neel, Sept. 26, 1999.

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